61.354

No. 736,288



ISSUED June 14, 1966

**CLASS** 166-16

CLASSIFICATION

GROUP

## CANADIAN PATENT

LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

APPLICATION No. 897, 460

FILED

PRIORITY DATE

No. OF CLAIMS

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#### LINER EXPANDER

This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

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In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 25 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the vall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the vall of the casing and effect a fluid-tight seal.

In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 23 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential screw element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft 16.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein  $P_{c}$  is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screv 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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I CLAIM:

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- 1 1. A device for expanding a metallic liner inside a conduit which device comprises a shaft element, an expanding die member attached to said 2 shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft 6 between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft 8 to contact said expander member and to maintain said expander member against said liner-forming member, whereby said liner-forming member is urged against 9 10 said liner by a substantially constant force.
- 1 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said 2 3 conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
  - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 4. The device of Claim 3 wherein said compression means comprises 1 5 a differential screw connecting said spring member and said shaft.
- 1 5. The device of Claim 3 wherein said stop means comprises a 2 sleeve-like element connected to said movable bearing plate member and 3 slidably positioned on said shaft and a member connected to said shaft to limit the travel of said sleeve-like element.
- 1 6. The device of Claim 3 wherein said columns have a rectangular 2 cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said shaft. 3
- 1 7. A device for installing an expanded metallic liner in a conduit 2 which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable out-5 wardly therefrom to contact the liner; a conical expanding member slidably 6 positioned on said shaft between said shaft and said arm members to urge said 7 arm members outwardly from said shaft; a plurality of slender columns, each 8 having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, 9 each slidably positioned on said shaft and contacting opposite ends of said 10 11 columns; limiting sleeves attached to each of said bearing plate members and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members outwardly with a substantially constant force.

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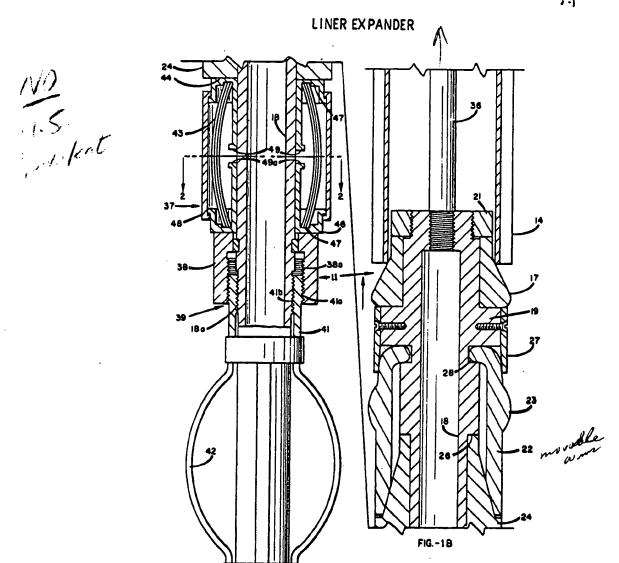
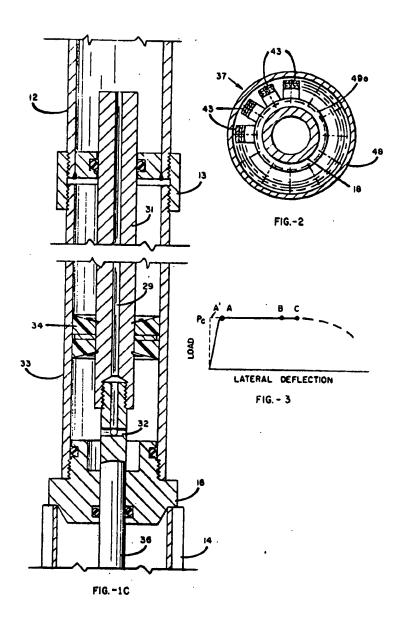


FIG. - 1A



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3. The device of Claim 2 standar, and counters from spring noder comprises a planning of columns disposed account wild shaft, a filer bearing place centur and a second bearing place scober, such of said bearing place members contacting opposite code of said columns, at least one of said bearing place members being sevenily positioned on said what's and being in contact with said come member, stop many commerted to said starts to limit the axial traval of said monthly bearing place member along said shaft, and compression means for maintaining a lateral derication in said columns.

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- . A, the device of Claim 3 wherehe well compression means comprises a \$100mm/cA, surve commenting and spring number and said shaft.
- 5. The device of Claim 3 wherein said step means comprises a alcove-like element commerce to exist covering these means and standar goaltices on raise shaft and a sunfor commuted to said shaft to have two troops of exist alcove-like element.
- 6. The devies of their 3 wherein sold column have a meaturpular errors—pretion, the width being greater than the Wildmone, and being the wider free sweet to the dissector of mild short.
- 7. A gerien for installing on expended ustallie liner to a cominti which comprises a systemical shade clustery on expending the system manded on mid shall, said ble senter comprising a planelity of are senters disposed stangentially amount the sectories of said shaft and buying provisals outstres to contest the liner; a contest expending maker alidably partitioned on said short between said short and maid are madened to unpersaid re ceterally from said short; a planelity of element columns, cash paring a long reutragular come-section and disposed stransferentially short suid chaft; an upper bearing plate seemer and a lower bearing plate stater, each elidably positioned on sale shart and contacting opposite unio of sale my limiting alseros uttended to each of still tearing plate numbers and although positioned to said shall; a shoulder number on said shall; a differential serve almost commeting will shoulder and still staft to apply a besting load to mid enimary said thouless being empayable with the Limiting starre semected to entil lower bearing plate mester, whereby the arial travel of said bearing plate members is listing; said column weathers brunestiting their buckling look to each erm nembers to urgs said arm meters cutourdly with a substantially constant force.

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#### LITER EXPLICIT

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An object of the present devention is a florier to applying a concreat force to an expending die or other sixilar expension on that a preselected maximum force to assarbed against a work piece. Another object is an improved expending tool for installing mobilite linear is a condult, which expending tool our apply so greater then a predetermined force to the linear heing installed in the opinist. Still number object of the investion is an economical and easily followinds constant force opening device. A further object is a regard, cosy-to-counts expending tool contains such a spring device. These and other objects of the investion will known apparent by reference to the following description of the investion.

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My invention will be befor understook by reterense to the following description and the measuremying drawings wherein:

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The expending tool, comprising the first-stage die and the secondstage die is drawn through the liner to expend it in place in the contag. Du first-stage die provides a gross deformation of the liner on that it is expended externelly against the well of the contag. The second-stage die them passes through the liner and perform the final agreement to exceed the inner surface of the liner and to service more over contact brises the liner and the well of the caring and effect a finid-light scal.

In operation, the liner setting tool is assembled at the surface, so described there, and a glass theth saturated with a restance material only be unapped around the corrugated ishe to form the liner. The assembly is lovered into the wall as the leastion at which the liner is to be set. A Liquid, such tegrang 29 provided in political rol 31, through ports 52 and into syllader 35 consected to the upper and of the shoulder 16. Upon the application of finish proviours to the splinder, the pietes 34 secured to polished red 31 notes specially in splinder 35. As shows, rot 36 commonts polished rod 31 and short 13 spon shieh is nowbed the first-stage expending die 17. Then the piston % note would through the splinter 35 the expending die 17 mil the secondstage die 22 are draw upwertly into the corrupted liner It and "iron out" prison in the liner, so that the expended liner may contest the famile well of the casing in which it is bring installed. Poritioned on the shaft believ the expending senter th is a countent turce spring master 37 which is employed to may the expending number against the emphating error 22 with a substantially sometant force. The force exacted against the arm members being substantially sometant, the force transmitted through the arm amphers to the lists and to the during will be substantially according an time either sticking a tool in the casing or repture of the caring is precluded. Or source, the three gradiest by the spring mester in presslected so that the frictional



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forces between the tool and the liner and the pressure exerted apriled the oneing are minimized at pressurations safe levels. The contract force spring makes assures that the context pressure between the liner forming portion 25 of the sum 22 is great enough to provide the dorinal deformation of the sad-

The speciest force spring season 77 is alignly specied on the shaft of seal hald between the expending alongst 26 and a splinarical lower shoulder season 35 towing a portion of a differential server alones 35 which between the localing on spring number 77 to shaft master 16. The differential server alonest comprises shaft under 16 on the certific of which are set said threads life, the lower shoulder number 18 provided with funds threads 35s and thinkle number \$1 provided with threads \$10 on the certific set that installe, respectively, to suppose with threads the seal \$10 on the certific set the installe, respectively, to suppose with threads on the shaft and the shoulder. The bod sets of threads are source, such as against motified square, or form threads, to withstand very high loads and differ in prich so that mouther 35 is several to the shaft in a received relative to thinkle \$1. The character 36 is several to the shaft in received relative to thinkle \$1. Implicationally, but it is not true to revote on the shaft. Finally attached to the lower set of the thinkle is a friction maker, such as but springs \$2, a sparalically setted of friction year, or other such device for frictionally angular with the incide wall of the angular to occurs the thinkle against totation with respect to the shaft. Profundly, the direction of the character with the pitch, or load, or turnels 15s is slightly greater than these of threads 35s, with the pitch rettle being alone to unity. In this success, clock-vine resolution of the shaft relative to the thinkle success shoulder appears 35 to advance upward allightly and a congression load is covering accept threads on a chart approximately 1.7-inch outside dissects and tive out threads an a chart approximately 1.7-inch outside dissects and tive out threads.

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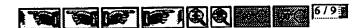


Quantiest force spring element 37 comprises entires element \$5, estentiageously constitute of a plurality of alongsted column disposed around shall 18. Upper beauting plate number by to to contact with the apper ands of the entires and is although positioned or chart if to brecord the force of the spring longitudinally against the bottom and of expenden number \$4. Lower having plate number \$6 contacts the lower ands of the columns and is noved against plate stands by leastlested in lower ands of the column and is noved in season of the shart by leastlested movement \$7. Greaves \$7 are provided in made of the bearing plates, to form an upper and an lover case, into which the case of the column are inserted. These growes any be despited to another cavely an artist from the spring mechanism and to protect the column to the spring mechanism and to protect the column to the spring mechanism and to protect

A norms for limiting the defination of the columns to required. Although the column element functions is a bunkled contition, application of . properties compressive land thereto would seems total failure or repters of the a. Therefore, a pair of stope by making are provided for this purpose. on, the stope are rigidly commuted to the bearing plates, and, in effort comprise upper and lower limiting stacres positioned on the shaft to alide longitudinally thereon. The ends of the stops may nowe toward, or enay sk other so the look in the spring number vertes. Lover sleeve him id from mosting dams by hower abouldar 50 accesseded to the electr. 18. Mrsever, the spacing between the sade in much as to limit the longitudinal travel of the bouring plate mechane on they more together to prevent personnt stice of the column element \$3. Various elternative masse for preventmage to the column element may also be employed. For example, plas or rings someted on the sheft may serve as stops, or the over 40 provided with suitable connections may be exployed for this purpose to limit longitudical and/or lateral seffection of columns.

The columns of the calmen visuant 4) may be arranged around the coart 16, which as shown here three a parties of the body of the spring ferring, with make of the columns fitted in the reces 57. The solumns may be

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ritted closely together as shore, or say he spaces around the race, with separature used between them to maintain the desired spacing. The runbar of columns employed will depend upon column characteristics and the materials of construction. For example, the eleminater ratio of the column may be varied widnly, and the column under say he recent, flat, flund or himsel. The preserved construction is a thin, element calculated the races shaped to the column and the tousies sain, from to move within the races shaped to the column at the tousies sain, from to move within the races shaped to the column are queries and loss alloy steels, devoting and minular-depends establishes are queries and loss alloy steels, devoting and minular-depends establishes steels allow and other similar materials providing estimated experts, the high which allows and other similar vidual columns are or long revises plant cross-section, with the tidth bring greater than the thickness, and arranged so that the under zoos of the notume is someth to the atmenter of the about two acts hering the loars commit of inertia, e.g., outwardly may from the about 15.

For example, a group of columns 0.167-inch thick by 0.838-inch wife by 10.636-inchew long, with the ands younded, were fabricated from h.f.S.I 1380 sheel, quantied and draws at 775°F. Bush column was found to require a critical compression loading of 350 pounds in order to buckle the enture.

After bushing, the columns were found to have a very flat spring thereteristic, as shown in Figure 3, therein P<sub>0</sub> is the critical bearing load and point of represents the load and deflection at which the stress in the extense fibers of the delumn except the yield point of the untertal. Theoretically, the shape of this spring characteristic energy is described by source 04'AEO. Actually, their curve is described by 0AEO due to friction in the system. Potote A and B regressest typical scraing limits, thinh, of course, say be varied according to the application for which the spring to destigand. For example, where a large number of flexing system are not entertained, a working atrees just below the yield point may be used, while with a great number of flexines, the working stress may be held to less then the sufference limit of the sectors of numbers. It is above-manifound teachs, the lateral startaction was limited to

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approximately one bush, at which the longitudinal deflection was approximately 0.207 inches. From more deflection to the section deflection, the \$50-pound loading was found to be substantially sometent.

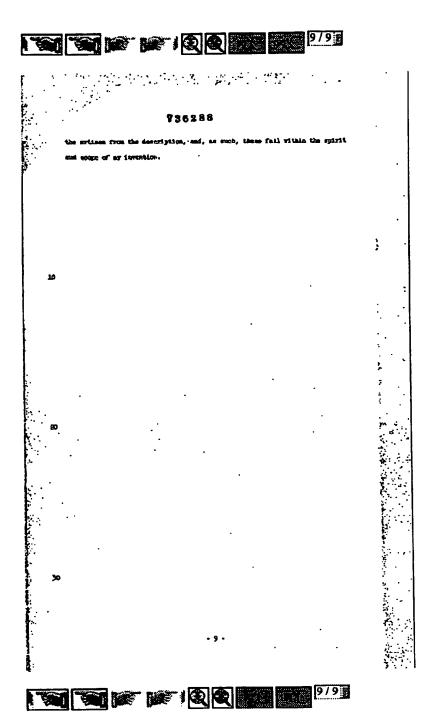
In mother test a spring dowing was built, as shown, oughning 80 columns, each having a critical bushing loss of 1250 younds. The internal definition was limited between 0 and about 3.00 inches by superprintely positioning the stope. Once compressional lossing, the spring element bushled at echetastically 25,000 pounds and from a longitudinal defication of 0.04 inches (making) to object 0.15 inches the loss remained substantially at 25,000

Or course, in designing a spring element as above it is advantagement to obtain the greatest possible value of longitudinal defluction for specified values of ladoral deflection and articles bushling load, while unintelling the atrees level in the columns at a cafe level. The preferred columns, therefore, are laminated, as shown in Figures 18 and 2, with militals flat analysis united to seek columns.

In the operation of the above expending tool for setting a lines in wall mains, the undo-up tool is lovered into the sell as sectional above, with the erec 22 in the retreated position. Sees the tool is at the Sentrol level, the sell taking is revolved. The fristion number of compact with the wall of the enemy and prevents thinkle of tree revolving. But a several revolutions of the taking, hower shoulder 35 is novel momenty by differential error 39 to bushle spring almost 37 which has a predeferminal critical bushling lead. Side lead is transmitted operating against the lower one of expender 36, and its topered surface is engaged with the tapered surface on the Louise of the orne 22 to urgs the term contently vite a substantially constant force proportional to the critical bushling load of the spring almost. Subsequently, the expending tool is passed through the lines to append it in the caping in the means described by a labelone.

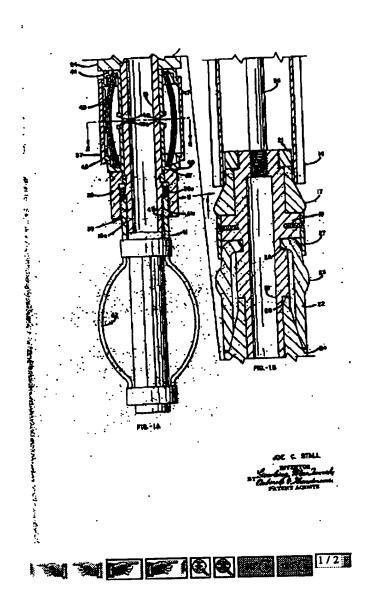
The foregoing concription of a preferred embeliant of sy investion has been given for the purpose of compilification. It will be understood that various medifications in the details of assortantion will become apparent to

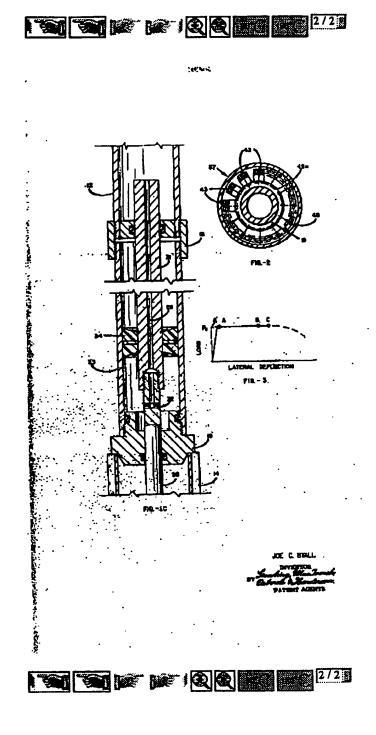
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